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PROTECTION OF THE ENVIRONMENT

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HEAVY OPTICAL GLASS IN CONCRETE FOR RADIATION PROTECTION

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A new-generation, high-strength, ultra-heavy, reactive-powder concrete for radiation protection is proposed. This superconcrete is obtained by making total use of TF-10 silicate-lead glass cullet as fine and coarse fillers introduced in dry form into the concrete mix.

Key words: disposal, optical glass, composition, concrete, protection, radiation, properties, density, strength.

The need for radwaste disposal, reliable and durable protective structures for nuclear reactors and isolation of x-ray rooms requires a new and effective material with universal protection against γ-rays and neutron radiation [1, 2]. Ultra-heavy concrete for radiation protection is such a material. Owing to its high density this concrete absorbs γ-rays and the hydrogen in the chemically bound water provides attenuation of neutron radiation [2].

In the present article we propose for radiation protection a new-generation, high-strength, ultra-heavy reactive-powder concrete fabricated using dry mixes. Just as the idea of ultra-strong concrete, the idea of creating a new-generation, high-strength, radiation-protective concrete (superconcrete) stronger than conventional concrete is not new. This is evidenced by the successful practice of using building materials, including superstrong heavy concretes classed as V80 and higher strength, in foreign and domestic industrial [3]. The published data on radiation-resistant materials incorporating commercial glass have made it possible to frame the key aspects of the development of the new-generation concrete by analyzing the published data on radiation-resistant materials with the use of commercial glasses:

– possibility of using dry modifying additives and dry reactive-powder concrete mix;

– use of heavy silicate-lead glass to attain the high density and strength of the ultra-heavy superconcrete.

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The new-generation, high-strength, ultra-heavy superconcrete for radiation protection was obtained by using ground TF10 silicate-lead glass as fine and coarse aggregates, disperse bonding filler and disperse plasticizer carrier, which are introduced in dry form into the concrete mix. The radiation-protective concretes are densified by optimizing the component ratios of the dry concrete mix: bonding material, filler and modifying agents. Aside from the factors associated with the recipe, technological factors also significantly affect the properties of radiation-protective concretes. These include the workability of concrete mixes mixed with water and the choice of methods used to mold and compact them. Glass-based super- and hypersuper-plasticizers make it possible to obtain ultra-heavy high-strength concretes with low W/C ratio (W/C = 0.24). Decreasing W/C increases the density and decreases the overall porosity of the concrete, as a result of which the physical-technical and hygrometric properties of radiation-protective concretes change [3, 4].

On this basis we shall present the key theoretical prerequisites for using heavy glass as an aggregate in concrete. Optical glass in the form of crushed cullet meets the specifications for elevated density and possesses minimal water absorption. This eliminates migration inside the cement system, which has a direct effect on the development of high-durability high-strength superconcrete with low ratio W/C. Heavy silicate-lead glass possesses high radiation resistance, thermal expansion coefficients close to that of the cement matrix and relatively low elastic modulus (compared with metal), which gives the optimal elastic modulus ratio between the cement matrix and aggregate. In addition, lead

glass is highly resistant to bio-corrosion, which is very important for repositories under the conditions of soil biological corrosion. The efficacy of using optical glass cullet is also confirmed by studies which have established that TF-10 optical glass is a low-reactive aggregate. The chemical composition of heavy optical glass is represented by the following oxides (content by weight, %): PbO — 70.9; SiO_2 — 27.03; Al_2O_3 — 0.3; K_2O — 1.27; and, Na_2O — 0.5. At the same time an important drawback of glass is its smooth, glossy surface which contrasts to the rough surface characteristic for many crushed rocks and is responsible for the reduction of the bonding between of the glass filler and the cement matrix as the concrete hardens. For silicate glass this situation remains even after the glass has been crushed. On the other hand the glassy structure and different metal oxides present in the glass promote constructive chemical interactions with the hydrolyzed lime that precipitates as the cement hardens.

The aggregate and filler based on TF-10 optical glass cullet are chosen on the basis of the following properties of the glass.

TF-10 Glass Properties

Density, kg/m^3	5100 – 5200
Microhardness, MPa	20 – 25
Strength, MPa	120 – 200
Elastic modulus, GPa – 55.3	
Poisson ratio	0.2
Specific heat capacity, kJ/(kg · K)	0.376
Thermal conductivity, W/(m · K)	0.621
CLTE 20 – 100°C, K^{-1}	8.1×10^{-6}

The task of developing high-filled concretes with maximum density was framed taking account of all the positive characteristics of the glass taken together.

The key properties of the new-generation radiation-protective concretes obtained using dry mixes and optical glass cullet are presented below.

Physical-Mechanical and Technological Properties of Optical Glass Based New-Generation Concrete

Density, kg/m^3	3800 – 4300
Workability grade	P3 – P5
Conical shrinkage, cm.	8 – 12
Strength for different uses (concrete class), MPa	20 – 1000 (15 – 80)
Maximum water absorption, wt.%	1 – 1.4
Open porosity, %.	3.80 – 5.93
Average pore size, μm.	0.116 – 1.378
Shrinkage, mm/m	0.25 – 0.31
Dynamic elastic modulus, MPa	$(41 – 42) \times 10^3$
Freeze resistance, cycles.	> 500
Linear attenuation coefficient for γ-rays, cm^{-1}	0.27 – 0.35
Radiation resistance	0.9

The development of the new-generation concretes based on optical glass, a byproduct of the glass industry, makes possible a comprehensive solution to two very important problems, one technical and the other ecological [4 – 6]. The first problem is the development of new effective building materials for radiation protection and the second one (the ecological problem) is solving the problems of resource conservation and recycling of technogenic wastes.

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